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Coast Erosion Protection Works

on the

Case System in British Guiana

By
GERALD O. CASE

*Associate Member of the American Society
of Civil Engineers, Associate Member of
the Engineering Institute of Canada,
Vice-President of the Tidal En-
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TO VAIL
JAN 1921

Preface

IN view of the fact that millions of dollars have been spent on useless coast protection works on the coasts of the United States of America, and particularly on the coast of New Jersey, the author thinks that no apology is needed for the present work which gives the details of the investigation made to ascertain the causes of the serious erosion in British Guiana (S. A.), and describes the permanent works which have been carried out to protect over 50 miles of coast and prevent further ravages of the sea. While no two shores can be treated exactly alike in order to prevent erosion, the problems which presented themselves for solution in British Guiana have in many respects their counterparts on the New Jersey Coast.

Millions of dollars were spent in British Guiana in erecting bulk-heads of vertical sheet piling, wave screens and other works of a similar type to those built on the New Jersey coast and with the same result. Not only were such works ineffective, but they actually caused erosion.

GERALD O. CASE,
522 Fifth Avenue,
New York,
January, 1920.

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Introduction

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B RITISH GUIANA which is bounded on three sides by three different countries—Venezuela, Brazil and Dutch Guiana—and on one side by the Atlantic Ocean, is the only British Colony on the mainland of South America. The area of the Colony is computed to be 89,480 square miles, it is therefore as extensive as the combined area of England, Scotland and Wales, and about twice the area of the State of Pennsylvania.

Sugar with its allied product of rum constitutes the most important industry of British Guiana. There are also considerable areas of rice and cocoanuts. In 1918 the total value of imports amounted to \$16,292,249, a large part of which were from the United States, and the total value of exports was \$14,799,316. Practically the whole of the cultivated lands of British Guiana and all the chief towns and villages are situated on the front lands, which are flat and from 3 to 4 feet below the level of high tide. The reclamation of the coast lands of British Guiana was commenced by the Dutch about the year 1750 and afterwards continued under British rule. The maintenance of the sea embankments which protect the towns and cultivated lands of the Colony from inundation by the sea is therefore of primary importance to the Colony's existence. The upkeep of the sea dams was for many years left to the estate proprietors and as more land gradually came into cultivation, it was found that the flow of water from the artificial drainage channels soon caused erosion of the foreshore. In his comprehensive report on British Guiana made in 1919, the Hon. C. Clementi, Colonial Secretary, reviewing the history of the coast protection works of the Colony, states that the adjacent proprietors emulated each other in endeavoring to divert attacks of the sea from themselves to their neighbors. So grew up an irregular and unnatural coast line, in which each drainage outlet was a danger spot. Heavy expenditure was incurred by estates' proprietors upon sea defence* work of useless and often harmful design. Vertical sheet-piling and stone piled wave-screens only hastened erosion, while the true angle of groynes, their proper height above the foreshore and the importance of maintaining them in an impervious state was never understood.

When the sea defence expenditure of an estate became more than its proprietor could bear, the old line of dams was abandoned and retirement inland was effected without consideration being given to the consequence of such retirement to the adjacent estate. Thus the coast line grew still more irregular and the sea defence expenditure of all owners of coastal estates steadily increased. In 1883 the Director of Public Works was empowered to make regulations for protecting the foreshore, to supervise all sea defences, and, with the assent of the Governor-in-Council, to compel the execution of works necessary for preventing erosion. In 1906 a body of Sea Defence Commissioners were formed with the Director of Public Works as Chairman and all sea defences on the East

*Local term and to denote coast protection works.

TO VNU
ANSONIA



Methods of protection prior to 1916. Earth dam with fascines in front



Methods of protection prior to 1916. Earth dam with fascines attacked by waves

Coast were vested in the Commissioners, who were given power to levy assessments in order to pay for work done. In 1913 the ordinance was amended and all sea defences were vested in the Director of Public Works and it was provided that the Public Works Department should execute all works, and that one-fourth of the cost of all sea defence works should be defrayed by the Government and the remaining three-fourths by the proprietors of estates and villages. Erosion of the foreshore, however, steadily continued and consequently the difficulties and cost of protecting the sea dams steadily increased.

Work Done by Sea Defence Commissioners

WHEN the Sea Defence Commissioners took over the East and West Coast Districts, there were long lengths of exposed dams protected by fascine work* and various wave screens and stretches of vertical sheet piling. While making little or no effort to pull out or modify such structures found on the coast when they took over the district, it must be stated in justice to the Commissioners that they appear to have recognized the advantages of utilizing the forces of nature to build up a natural protection instead of fighting the sea and they experimented with low timber groynes. Owing, however, to lack of expert knowledge as to the correct length, angle, distance apart, etc., at which the groynes should have been placed, the results were not altogether satisfactory.

As a direct result of difficulties arising from sea defences, Plantation Bel Air, Hague, La Jalousie, Windsor Forest and Vreed-en-Hoop were cropped and went out of sugar cultivation prior to 1915. In that year Sir Walter Egerton, K. C. M. G., Governor of British Guiana, recognizing the seriousness of the position, appointed a Commission to enquire into the Colony's sea defences. The Committee in their report state that;† "Serious breaches by the sea at Montrose, Success, Triumph, Mon Repos, D'Endraght, Lusignan and elsewhere on the East Coast, Demerara, have revealed the danger to the entire coasted industries of the Colony, as well as to the City of Georgetown involved in this growing menace of the sea." In moving the adoption of the Organization Committee's Report of the Sea Defence Commission on January 17th, 1916. the Hon. J. J. Nunan, K. C., said: "The emergency is too grave to waste words upon it. Our inadequate and unscientific sea defences have been broken in several places within a few miles of Georgetown during the four weeks of the Commission's existence. The high Spring tides have flooded through two great breaches at Triumph since we last met and have closed the public road during several hours for some days, washing away the parapets and causing great general damage. The matter is vital. No vehemence of ours on this Commission could exaggerate the importance of the issue . . . It is also whether we should allow the sea to encroach more and more upon the land, allow the sugar and rice industries to be ruined and watch with equanimity

*Brushwood Mattress Work.

†Report of Sea Defence Commission 1916.



Methods of protection prior to 1916. Wave screen



Methods of protection prior to 1916. Stone filled wave screen

until Georgetown (taken in flank) has to retire to the sand hills and the river estates are left (and only for a short time as they now realize) the last survivors of an industry built up with brains and millions of dollars by a different type of man. . . . Gentlemen,—This is a Council of war. There is no mistake about it. Our enemy is the sea and like a skillful enemy he is behind a hill, metaphorically speaking. I wish he were so physically. It is our business to find out what we do not know now, what hitherto we have hardly begun to find out, viz., what he is doing, where he is next going to attack, whether that is a feint to enable him to do greater damage elsewhere and why he is doing it, what are his forces, what are his weak points and whether by a kind of jiu-jitsu we can use his own strength against himself . . . We have no time to lose if we mean to save the business reputation and general repute of the Colony."

The seriousness of the position is further emphasized in the report of the Commission. The Commissioners state that: "The question of sea defence has apparently been looked at by a succession of engineers and others from behind the dams. The actual causes of erosion have not been studied and defence works have been put up without regard to the actual development in the sea in front of them. Works which might be suitable for one cause or form of coast erosion may be ruinous folly when dealing with another. One engineer after another has come and gone and generally left behind him a reputation for large and increasing expenditure barren for the most part of permanent result. Millions of dollars have been spent and the sea steadily advances. No sequence of work can be traced. The scheme followed by one officer has been almost invariably abandoned by his successor." An idea of the enormous amount of money spent in unsuccessful attempts to combat erosion may be gained by the fact that in 1915 the annual maintenance expenditure was \$276,381. In the Spring of 1916, it was agreed that expert advice must be obtained as to the best means of defending the foreshore permanently against erosion by the sea. Accordingly the author was engaged by the Government to make a report and prepare plans for a comprehensive scheme of permanent protection Works. The author's report on the East Coast of Demerara was published in June, 1916. The report on the West Coast of Demerara in August, 1916, the report on the Essequibo Coast in June, 1917, the report on the Corentyne Coast in July, 1918, and the report on the Islands of Wakenaan and Leguan in March, 1919.

State of the Protection Works in 1916

THE inspection made of the whole coast line convinced the author that the report of the Sea Defence Commission under, rather than over, estimated the seriousness of the position at the beginning of 1916. The breaches which had occurred prior to the date of the Commission's report, drew attention to the weakness of the sea dams in several places, but the author had to point out in his report that there were many other places where serious breaches might occur during any rough high tide. Between Good Hope and Nog Eens for a distance of about



Methods of protection prior to 1916. Fascine groynes. Note damaged groynes in background



Type of sluice used prior to 1916.

4,000 feet the existing defences on the East Coast, although not actually breached, were in the worst possible condition and in fact they were subsequently breached for a length of 1,000 feet before it was possible to start the permanent works.

On the East Coast between Clonbrook and Grove there was, in 1916, over 7,000 feet of continuous dam, close to the main road, in an extremely bad condition and liable to be destroyed at any time. In many other places in the early part of 1916, the sea defences were in a hopeless condition and were only kept up by continuous and ruinous expense.

The whole length of the sea dams in front of Plantation Success, Triumph, Mon Repos, D'Endraght and Buxton on the East Coast had to be abandoned in 1916 on account of the serious breaches.

The inspection made of the West and Essequibo Coasts also showed that the heavy maintenance expenses were likely to continue until a comprehensive and permanent scheme of Coast Protection Works was carried out.

The failure of the works executed prior to 1916 appeared to be due to several causes. Firstly, there had been no continuity of policy. One Director of Public Works had frequently pulled out the work done by his predecessor. Secondly, coast erosion and coast protection work is a special and highly scientific branch of Civil Engineering and it has not been found in practice, nor is it expected, that a Director of Public Works, however well qualified he may be, could be expected to have an expert knowledge of this subject. Each Engineer on his arrival in the Colony had been seriously handicapped in studying this problem by the conspicuous absence of reliable data as to the coast line changes and the effect of works constructed on the foreshore. Thirdly, the works were not properly supervised; and many of them were destroyed owing to their not having been kept in a proper state of repair. While condemning, in his reports, in the strongest possible language a system which had led to an enormous annual expenditure without any compensating benefits the author thought it necessary to draw attention to and endorse the opinion of the recent Sea Defence Commission that the present Director of Public Works, the Hon. E. C. Buck, owing to his multifarious duties, had not had time since his arrival in the Colony to properly study the problem and had also been seriously handicapped by lack of data.

In fairness to Mr. Buck's predecessors it must be stated that they repeatedly drew attention to the weakness of the existing system. In his annual report for 1888 the Director of Public Works stated:—"I greatly regret that the limited staff at my disposal has prevented me making exhaustive observations, without which such problems (coast protection) cannot always be successfully solved. There can be no question that it is both wise and profitable to collect the most accurate and detailed information respecting all changes along the sea board, and as far as possible, the effects and causes thereof. I cannot too forcibly urge upon the Government the importance of such records. They are beyond doubt absolutely essential to the successful solution of the problems now presenting themselves (erosion of West Coast), and when compiled, should be at all times open to the inspection of those interested."



*Bulkhead at Lusignan. East Coast
Methods of protection prior to 1916. Constructing vertical sheet piling*



Same sheet piling bulkhead being attacked by waves



Sheet piling bulkhead at Lusignan demolished by sea. Note scoured foreshore



Bulkhead at Lusignan destroyed by sea after scouring out of foreshore. New sea wall constructed for permanent protection



Reinforced concrete sea wall



Reinforced concrete sea wall

Permanent Protection Works

THE scheme of protection work in British Guiana is to date the largest permanent coast protection work ever carried out. The works now completed or projected will afford permanent protection to $52\frac{1}{4}$ miles of coast line of British Guiana. The total coast line is 270 miles but the unprotected balance is not now beneficially occupied. Owing to the importance of maintaining supplies of sugar and rum from the Colony, the protection works were put in the class of work necessary to be executed during the great European war. In order that the work might be speedily constructed the United States and British Government gave special and priority permits for material to be shipped.

After carefully considering the formation of the coastlands, the changes in outline of the coast which had taken place in recent years, the forces causing the movement of the foreshore materials, the causes of erosion, the causes of littoral drift and the available supply for building up the shore, the author advised the construction of the works enumerated in the following table.

The following table shows approximately the amount of work in the permanent scheme of protection:

Groynes:

Coast	No. of Groynes	Approximate cubic feet Reinforced Concrete
East Coast	38	197,600
West Coast	33	171,600
Essequebo Coast	23	75,000
Corentyne Coast	5	14,250
Wakenaam Coast	8	13,800
Leguan Coast	4	6,500
Total number of groynes	111	478,750

Sea Walls:

Coast	Lin. feet	Approximate cubic feet Reinforced Concrete
East Coast	25400	735,000

Reinforced Concrete Facing to Earth Dams:

Coast	Lin. feet	Approximate cubic feet Reinforced Concrete
East Coast	5,000	52,000
West Coast	14,500	190,000
Essequebo Coast	1,650	20,000
Wakenaam Coast	800	8,000
Leguan Coast	700	7,000
Totals	22,650	277,000



Case reinforced concrete groyne in course of construction



Case groyne partly planked up



Reinforced concrete facing to earth dam. Case groyne in distance

Sluice Runs:

Coast	Lin. feet (single wall)	Approximate cubic feet Concrete
East Coast	12,000	128,000
West Coast	6,000	64,000
Essequebo Coast	6,000	64,000
Corentyne Coast	400	4,350
Totals	24,400	260,350

Earth Dams:

Coast	Approximate number of lineal feet of dam
East Coast	23,200
West Coast	9,350
Essequebo Coast	11,000
Wakenaam Coast	2,450
Total	46,000

Diversion of Public Road made necessary owing to new Permanent Protection Work:

Coast	Approximate lineal feet of road diversion
East Coast	18,000
West Coast	2,000
Essequebo Coast	6,500
Wakenaam Coast	2,450
Total	28,950

IN addition to the execution of the permanent scheme a very large amount of work had to be done in dismantling and removing old sea defences—stone and timber wave screens, vertical sheet piling, etc.—which were causing erosion of the foreshore. Up to the end of 1919 approximately 1,500,000 cubic foot of stone alone had been removed from wave screens on the foreshore of the East, West and Essequebo coasts. These wave screens and vertical sheet piling were built at an enormous cost to protect the coast and not only proved useless, but in the author's opinion were undoubtedly an active cause of erosion.

The illustrations show the types of permanent works constructed.

The scheme in its entirety was designed in accordance with the widely known Case System of Coast Protection. The essential points of this system are firstly the utilization of the constructive forces of the sea to build up by long, low groynes a natural protection of shingle, sand or mud, to such a slope that the waves can harmlessly roll up the shore and expend their energy before reaching high water-line. The groynes being designed to collect both material moved along the bottom by waves and carried in suspension in the littoral current. Secondly, that where sea walls are essential, to build an elliptical and curved wall, the bottom part of which in stepped and in effect forms a continuation of the natural shore gradient.



Reinforced concrete facing to earth dam in course of construction



Completed reinforced concrete facing with case groyne in front

Waves cannot concentrate their striking energy on such a wall but have it gradually abstracted from them over a large surface. The curve of the wall and axis of the ellipse vary on different coasts according to differences in range of tide, slope of foreshore and other factors. Owing to conditions not being the same in all places, it was necessary to have two different slopes for walls on the British Guiana Coast. On some parts of this coast the slope of lower part of wall was approximately 2 to 1 and in other parts of the coast approximately $1\frac{1}{4}$ to 1. In order that material may be collected in front of the wall it is very important that the correct slope for the lower part of the wall be ascertained by careful investigation of local conditions.

On the East and West Coasts the groynes were placed 1,500 feet apart and were 750 feet long. On the Essequibo Coast they were built 1,000 feet apart and 500 feet long. The length and distance apart of Case groynes necessarily varies according to the range of tide, width of foreshore, nature of material to be collected and other factors which have to be ascertained before planning any protection works.

The angle at which the groynes are built out across the foreshore is another important factor in the success of any scheme of protection. After carefully studying the local conditions it was decided to build the groynes at right angle to the general coast line except one on the Corentyne Coast; the position of this groyne being in the estuary of the Corentyne river, it was decided to build it diagonally across the foreshore in a north-easterly direction.

The groynes across the foreshore forming training walls for the sluice outlets were designed to prevent the water therefrom being diverted along shore by littoral drift and forming a water channel close in-shore. The training groynes or walls were built 750 feet long and except in three cases on the leeward side only.

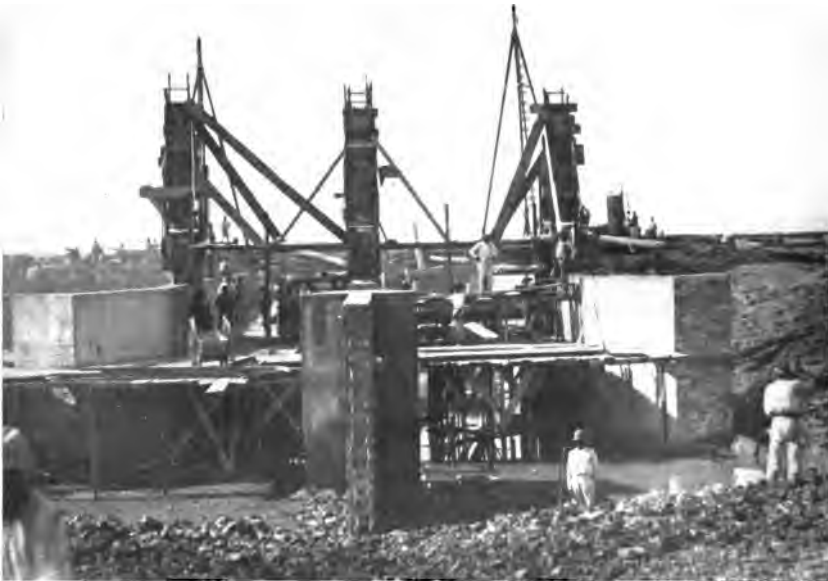
The sea walls, concrete faced dams, sluices, groynes and training walls have been built of reinforced concrete. The structural details and reinforcements for the works recommended in the author's reports were in accordance with the calculations and specifications of J. J. Hennebique, M. Am. Soc. C. E., President of the Tidal Engineering Corporation.

Commencement of Permanent Works

THE construction of the permanent works recommended by the author was commenced on the East Coast of Demarara in July, 1916. The permanent works on the East and West Coasts of Demerara, where by far the greatest part of the work is situated, were completed at the end of 1919 except for some of the groynes and two sluices, and a number of outlet training walls. A good deal of dismantling of old works has to be done in 1920 in order that the action of the Case groynes in building up the foreshore may not be interfered with. On the Essequibo Coast the works are now well in hand and should be practically completed by the end of 1920. The works on the Corentyne Coast and the coasts of Wakenaam and Leguan, which are small compared with the East and West Coasts works, are also now in course of execution.



Reinforced concrete sluice and sluice run built to drain lowlands and



Reinforced concrete sluice in course of construction



prevent erosion of coast protected by sea wall and Case groynes



Completed reinforced concrete sluice in line of sea wall



Sea wall Clonbrook soon after construction. Note exposed steps and pools of water



Sea wall Clonbrook after Case groynes had commenced to build up shore

The cost of these five schemes was estimated by the author as follows:*

East Coast Demerara	\$2,763,438
West Coast Demerara	1,223,663
Essequebo Coast	400,000
Corantyne Coast	30,000
Leguan and Wakenaam	59,456
Total	\$4,476,557

When finally completed it may be found that the cost of the whole scheme is a little less than the amount above given. It is, however, difficult to give an accurate estimate on the cost of dismantling the remaining old sea defence works.

THE new permanent protection works are being financed partly by loan raised in the Colony from local investors at 5 per cent. interest and partly by "benevolences" from proprietors of sugar estates. Ordinance No. 32 of 1916 provided that a charge of \$5 per acre should be paid by the proprietors of sugar estates in return for the issue to them of Treasury Bonds to an equivalent amount, bearing interest at 5 per cent per annum. The maximum annual acreage assessment for the sea defences is now \$1.14 per acre for estates and 57 cents for villages, the balance of expenditure being paid for by the Government.

A Sea Defence Department has been formed by the Government and the execution of the Coast Protection Works is now (1919) under the able direction of the Hon. J. Paton Auld, M. Inst. C. E.

In addition to the actual construction of permanent works and the removal of all vertical sheet piling, wave screens and existing high groynes, the author also recommended that measures be taken to prevent in the future erosion due to artificial causes.

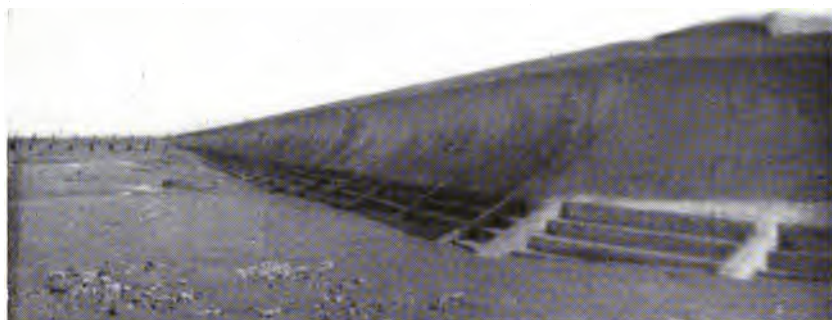
The cutting down of Courida and Mangrove trees on the seaside of the dams, which has in the past caused erosion, is now contrary to law, and the author recommended a strict enforcement thereof. The same remarks hold good as regards damage done to vegetation and the dams by straying animals.

Owing to the limited supply of shell on the East Coast the Government was advised not only absolutely to prohibit its removal from the seaside of the dams or sea-walls, but that estate-owners and villagers be compelled when clearing their sluice runs of shell to deposit the same on the foreshore on the windward side of the sluice.

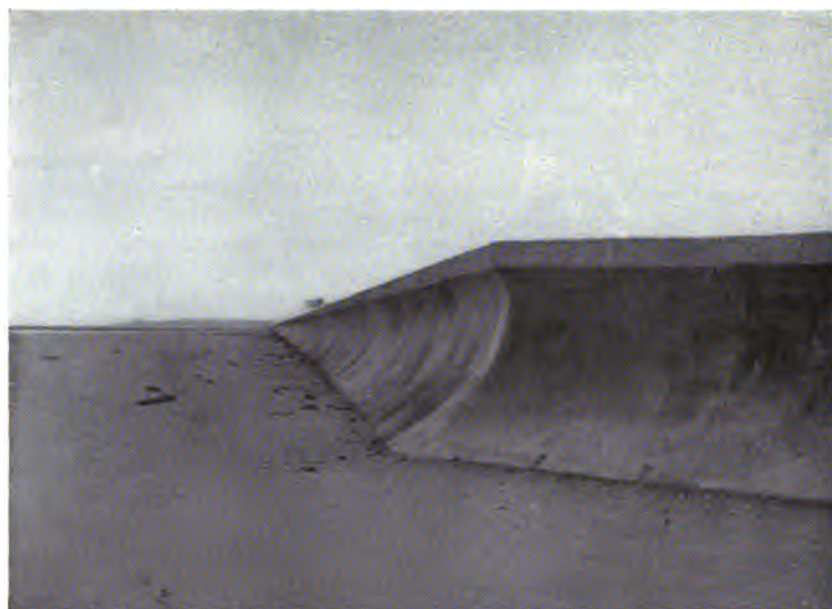
To prevent dead trees on the foreshore causing erosion the Government were also advised to have them systematically removed and that it be one of the duties of the Overseers to see that this is done in their districts.

The author also recommended that investigation be made to ascertain how far vegetation could be utilized to assist the groynes in building up the foreshore. Preliminary researches have already been made by the

*British Guiana Combined Court Document No. 21.



Clonbrook sea wall



Clonbrook sea wall after Case groynes had commenced to build up the shore

Department of Science under the direction of Prof. Harrison, C. M. G., and experimental planting has been started with satisfactory results.

In a report to the Government dated November 22nd, 1919, the author referring to the use of vegetation stated that:

"Experience shows that in places where sea defences are retired and a new line built some distance inland of the old line, that the area between the old and new line (which for a considerable time is protected against violent wave action by the remains of the old outer dam) very rapidly builds up where vegetation is quickly established and rapidly grows. This has been most noticeable at Success and Chateau Margot. In such situations vegetation is the most effective means of slowing down the littoral current and arresting sediment in suspension in the water. In some areas vegetation covers the surface very much quicker than in others, this being no doubt dependent upon the number of seeds washed in by the incoming tide.

In the bay now formed between Buxton and Lusignan by the retirement of the sea defences, there is a large area protected by the old public road from violent wave action. In this area vegetation is not covering the ground so rapidly as it has done at Success and Chateau Margot, and some trial areas have been planted with mangrove and rice grass. These experimental plots appear to be doing well and I would very strongly urge the systematic planting up of all bays formed by the retirement of the sea defences, so that the land may be as rapidly as possible built up by the aid of vegetation."

Result of Permanent Works

IN a report to the Government dated 6th November, 1917, the author was able to state that on the Lusignan, Beterverwagting and the Clonbrook Grove sections of the East Coast, where permanent works first began, "the condition of the foreshore is already improving at a rate beyond my most sanguine expectations. In front of the new Lusignan sea wall, the foreshore has built up an average of 3 feet 6 inches, and, in what were formerly the most eroded portions, to a vertical height of from 5 to 6 feet; while on the Clonbrook section where in the Spring of 1917 very rapid erosion was taking place, and where a part of the public road was washed away and the rest of it threatened with entire destruction, we now find the foreshore built up to a height of from 2 to 3 feet above the roadway."

In May, 1919, the author reported to the Officer Adminstrating the Government that "the beneficial result has far exceeded what I anticipated, when making reports on the East and West Coasts of Demerara, and I know of no foreshore in England, or elsewhere, where groynes have so rapidly accumulated material as they have done on the East and West Coasts. Between Kitty and Plaisance on the East Coast of Demerara the existence on the foreshore of the stone wave screens and other remains of the former sea defence works has, to a large extent, prevented the groynes rapidly building up the foreshore, but in all places where such wave



Sea wall Clonbrook before Case groynes had built up shore



Sea wall Clonbrook after Case groynes had commenced to build up shore



Sea wall Clonbrook. Shore built up by Case groynes

screens and other structures have been entirely removed the groynes already constructed have done remarkably good work in building up the foreshore."

"In front of the Annandale facade the groyne constructed has already done good work, and the low land, between the old outer earth dam and the reinforced concrete facing to the new line of sea defences, is rapidly silting up. On the Clonbrook section on the East Coast groynes have now been constructed in front of about 7,000 lineal feet of sea-wall. The sea defence works on this section were commenced at the western end and gradually completed to eastward. The sea-wall and groynes were constructed under considerable difficulties, as the sea swept over the site of the works at every high tide. At the end of June, last year, the sea-wall was completed up to the Mahaica Canal, and the sea prevented from overflowing the land. The groynes on this section of the coast have also caused a very remarkable amount of accretion. For a considerable length the foreshore in front of the wall has built up above the level of high-water-mark neap-tides, and the sea only reaches the sea-wall at high Spring tides. In front of the eastern end of the Clonbrook sea-wall the groynes have only recently been constructed to their full length, but the improvement of the foreshore is very marked, and I have no doubt that before the end of next summer the foreshore on this part of the coast will have built up to the level of high water neap tides. On the West Coast of Demerara the groynes constructed in front of Uitvlugt and Leonora have also done good work, the improvement of the Leonora foreshore being especially noticeable. On the West Coast a considerable amount of groyning still remains to be done, and I have no doubt that the groynes, which it is proposed to construct between now and the end of the year, will do equally good work as those already constructed."

In a report to the Government on the East and West Coasts of Demerara, dated November, 1919, the author stated that "I am of the opinion that the general situation may be considered very satisfactory. Wherever there is a clear foreshore (that is where old sea defences have been removed) the groynes are doing excellent work in building up the foreshore and I venture to state that there is every indication that the work when completed will be entirely successful in protecting the coast."

APPENDIX

Formation of Coast Land

THE Coast region of British Guiana forms a plain of marine alluvium which is traversed in places by lines of sand dunes. The deposits were undoubtedly derived from the silt brought down by the Amazon and carried along the coast by currents until it was finally deposited. By this means a tract of land was formed from ten to thirty miles wide of exceptional fertility, most of it from 3 to 4 feet below the level of the sea at Spring tides. The country in its physical features bears a close resemblance to Holland.* Prof. Harrison, C. M. G., Government Geologist, in a report to the Sea Defence Commission describes the geological condition of the coast line. He states that—"The present form of the coast of British Guiana, at any rate to the eastward from near point Kokali in the northwest and of Dutch Guiana to the mouth of the Mariwyne River in the extreme east, is of very different form to that it possessed until a geologically recent period. In the vicinity of Point Kokali there is evidence of a spur of the basic Guianian gneissose complex reaching to within a few miles of the coast; whilst the coast of French Guiana east of the Mariwyne River consists of that complex. From the vicinity of Point Kokali to the River Mariwyne there existed a vast bay or indentation of the land apparently of greatest depth and of broadest extension southward near the present Corentyne River. It was probably the estuary of a great South American river or more probably rivers possibly flowing from the Amazon region as well as from the districts which are now drained by the Essequibo group of rivers. The evidence afforded by the recently made deep borings shows that this indentation or bay was gradually silted up by the deposition of great beds of sand of very varying texture and of clay, many of the beds showing evidence that their constituents were derived from a nearby area of granitic or gneissose rocks. In the course of geological ages an uplift of the area occurred, the lines of river flow were changed and the coastland was bordered by vast areas of windblown sand dunes. Later these coastlands gradually subsided, this probably being accompanied by a compensating uplift of the extreme north-eastern area of the Guianan complex. The Guianan rivers traversing an area of geologically very ancient land were in their lower reaches no longer of a rapid rushing torrential nature and ceased to bring other than very finely textured sediment to the coast and it is this in part which has given rise to present difficulty of coast defence.

"The present shoreland alluvial is regarded as derived from the drift of the Amazon River and as having been gradually brought here by the Amazon current; but doubtless it in part consists of the rearranged highly comminuted material derived from the great sand dunes and their overlying marine and estuarine beds. Its thickness is not great, probably nowhere

*Vide Journal of the Board of Agriculture—July, 1907-April, 1909.

in British Guiana exceeding 200 feet. It consists very largely of silt and sand in very fine grains. . . . The grains have probably been alternately drifting and depositing, gradually lessening in size, during very many centuries. Very little sediment is now derived from the Guiana rivers. The land behind and below the marine alluvial deposits, geologically speaking, is very ancient land, the sedentary earths resting on the rock surface are more or less completely leached-out laterites, lateritic earths, kaolins and residual quartz sands and now contribute very little to the burden of the Guiana rivers either in suspension or in colloidal or in true solution. The little that may be borne in suspension by the waters of the upper reaches of the rivers is more or less completely deposited along the great reaches of relatively still water which forms vast settling ponds between each important zone of cataracts."

"The coastlands, therefore, have to be considered as an area of loose, more or less incoherent sediments which is not being added to appreciably by sediment derived from the mainland of the Continent."

The general evidence seems to prove that the present cycle of coast-line changes was started by an alteration in the relative levels of land and sea which caused the formation of a very wide foreshore at low tide.

There is no doubt that the coastlands of British Guiana at one time formed an immense area of foreshore, covered by the sea at high tides and dry at low water. A shell barrier was then formed and in course of time marsh land and tidal forests were formed behind. At the time of the first occupation of the country by Europeans the coast line was no doubt more or less stable except near the mouths of the rivers which cut through the natural shell barrier.

If left to nature it appears highly probable that the rate of erosion due to the gradual inland movement of the shell barrier would have been very small, perhaps negligible, and that the rapid erosion in recent years is to a large extent due to artificial causes arising from the empoldering of the marsh land and the construction of badly designed sea defence works.

In places where there were gaps in the barrier due to river outlets the area of sheltered water behind such naturally sea formed barrier then became silted up, being no longer exposed to violent wave action. The flood tidal current and in some cases the river current brought in sand and silt which was deposited at slack water and salt marshes were gradually formed. In the formation of salt marshes behind the sea formed barriers vegetation played a very important part. Currents brought in the silt and the vegetation organized and controlled the accretion and caused it to take place at a much more rapid rate than it otherwise would. Plants and trees which grew on the shallow sheltered area, covered at high tide but dry at low tide, slowed down the currents and caused material to be deposited which in their absence would have been held in suspension and moved away. Numerous marine animals dwelt among the plants and their remains and the decay of the plants themselves assisted in forming a fertile soil. The factors at work might be regarded as forming collectively a machine for building up a soil on the foreshore and reclaiming it.

On the Corentyne Coast the conditions are quite different from those

on the East and West Coasts. The Coast forms part of the estuary of the Corentyne River and is, to some extent, sheltered from severe wave action by the conformation of the shore line on both the British Guiana and Dutch sides of the river. This being so, currents caused both by tidal action and the discharge of river and drainage waters, have a relatively much more important effect in causing the movement of material than is the case on the East and West Coasts. The land forming the shore line and the West bank of the estuary of the Corentyne River is also much higher than the East and West Coast lands. While the latter is from three to four feet below the level of high spring tides, the coast land between 66 Creek and Skeldon, on the contrary, varies from about high water level spring tides to five feet above that level.

Foreshore Vegetation

On the British Guiana Coast there are three zones of vegetation which are of considerable importance with reference to coast protection. Firstly, on the foreshore itself below the level of high water neap tides. Secondly, on the sandy ridges above high water neap tides. Thirdly, the tidal mud swamps or littoral forests, extensive areas of which are found between the levels of high water neap and spring tides.

In the first zone *Spartina* Grass is the only vegetation which has so far been found to be of utility in assisting accretion. Several areas have recently been planted with this grass and on the muddy foreshore on the East Coast this grass is doing well and assisting in saving and consolidating the foreshore.

In the second zone we have the *Psammophilus halophytic* formation, which Mr. Bancroft, formerly Assistant Director of Science and Agriculture in British Guiana, states comprises, "sand-loving species of low growth which are essentially photophilous, i.e., incapable of enduring shade. This zone is flooded with sea water at intervals, being subjected to inundation at springs but not at neap tides. The formation is an open one, the plants being usually separated owing to the unsettled nature of the soil which is disturbed by high tides and winds. The species are for the most parts perennial herbs. The two dominant species are *Ipomoea*—*Pes Caprae* and *Canavallia ensiformis*. Along with them occur, more especially in drier parts, *Alternanthera*, *Sesuvium*, *Fimbristylis* and *Heliotropium*, and in wetter spots *Sporobolus*, and *Batis*. This formation occurs on the foreshore at Kitty, on the East Coast, on parts of the Essequibo Coast and on other parts of the coast line." On the higher parts of the sandy ridges we also have what Mr. Bancroft describes as the *Halophilous Forest* or Bush land on sand. The vegetation on the sandy foreshore being succeeded on the landward side by a taller growth. The associations are dominated by *Thespesia* and *Hibiscus tiliaceus* (Mahoe). Along with these occur *Bontia*, *Ruellia*, *Achryanthes*, *Cassia bicapsularis* and *Malachra capitata*. The trees are short with leathery leaves. The formation is comparable with the *Barringtonia* Association in Eastern Asia and Australia. Mr. A. Leechman who has made a study of shore vegetation in British



Sandy shore overgrown by vegetation. Courida swamp at back



Mangrove swamp flooded by spring tides

Guiana, states* that on the sand reef the first colonist is, so far as his observations go, *sesuvium portulacastrum*. This is later joined by *Alternanthera ficoidea*; and these two plants, of low-growing, creeping habit, form, when well established, a firm meadow upon which sheep and goats are pastured. This may conveniently be called the "*Sesuvium* Association." *Ipomoea pes-caprae*, the "Nany-foot convolvulus," flourishes on the sea side of the dam, and invading the "*Sesuvium*" meadow, becomes a conspicuous feature in the vegetation.

In the third zone we have the *Pelophilius halophytes*. To this formation, Mr. Bancroft states, belong essentially *Courida* and *Kiara* (*Laguncularia racemosa*). As also do *Sporobolus*, and *Spartina*. The shore at Sancretal Bay (Waini Mouth) furnishes an excellent example of this formation. The coast line from the Pomeroon River to the Waini Mouth and muddy flats on the East and West Coasts of Demerara consist mainly of this formation. It is also present on coasts bounding the Caribbean Sea where flat expanses of clay occur. *Courida* grows at its best here.

The *Littoral swamp forest* is dominated by the mangrove or courida along with *Laguncularia* and some other species. The distribution of the species is zonal; although the reason for this is not clear. Probably adaptability and fixation in the soil play an important part, although salinity may also be a determining factor. It seems probable, since the *Courida* association is nearly always present on the exposed coast, while the mangrove dominates the sheltered parts of the coast and the banks of the rivers near the mouth, that fixation is an all-important factor, more particularly in the early stages of growth.

Foreshore Materials

The foreshore consists largely of sling mud with localized deposits of caddy on top of the mud and ridges of broken shell at or just above high water line.

Sling mud is a non-calcareous plastic clay containing some sand as shown by the following analysis:†

Sling Mud		
Insoluble residue (Sand).....	48.68	per cent
Silica (SiO ₂)	11.74	" "
Alumina + Ferric Oxide (Al ₂ O ₃ .Fe ₂ O ₃).....	27.44	" "
Lime (CaO)	nil	" "
Magnesia (MgO)	1.88	" "
Combined water, organic matter and loss.....	10.26	" "
	100.00	per cent

Caddy which in places collects on top of the sling mud by natural or artificial causes consists of fine sand mixed with clay and calcareous matter as shown by the following analysis:

*Report of Sea Defence Commission, 1916.

†Vide report of Messrs. Case and Gray, 1900.

Caddy		
Insoluble residue (Sand).....	68.12	per cent
Silica (SiO_2)	5.95	" "
Alumina Ferric Oxide ($\text{Al}_2\text{O}_3\text{Fe}_2\text{O}_3$)	12.34	" "
Lime (CaO)	5.07	" "
Magnesia (MgO)	1.18	" "
Carbonic Anhydride (CO_2)	3.67	" "
Combined water, organic matter and loss.....	3.67	" "
	100.00	per cent

The foreshore of the West Coast also consists of sling mud with localized deposits of caddy on top of the mud, but the ridges above high water line are chiefly composed of sand, there not being nearly as much shell on the West as the East Coast; there is also a larger amount of sand on the foreshore, and in places it completely covers the local clay.

While the lower part of the foreshore on the Essequibo Coast consists largely of sling mud with a localized deposit of caddy, on the upper part of the foreshore there is a comparatively large amount of sand, and in many cases sand ridges are to be found at high water line, which in places have entirely covered the artificially made sea dams.

Changes in the Outline of the Coast, 1792-1916

In order to ascertain the outline of the coast, the position of the dams and other works, built in recent years, it was necessary to make a new survey of the East Coast.

A comparison of the old maps and the new maps showed that the rate of erosion was by no means uniform. Periods of erosion were in places followed by periods of accretion; the accompanying tables show the actual gain or loss of land, at the centre of each estate as indicated by the seaward edge of the courida. The edge of the courida is, however, not necessarily the high water line of ordinary tides, but no doubt indicates fairly accurately erosion or accretion of the coast. In the new survey a contour line (53.50 Georgetown datum), the level of ordinary high water, has been put on and this will enable future changes to be more accurately ascertained.

The evidence available seems to show that between 1792 and 1874 the average rate of erosion of the East Coast between Kitty and Mahaica was 10.57 feet per annum, between 1874 and 1890, 79.00 feet per annum, and between 1890 and 1916, 23.80 feet per annum. Between 1792 and 1874 Lusignan Spit was formed, the maximum width of the accretion being nearly 6,000 feet; this accounts for the low average rate of erosion between 1792 and 1874.

EAST COAST

Alterations in Coast Line Between 1792 and 1874

Estate	Erosion between 1792 and 1874. Ft. Lin.*		Accretion. between 1792 and 1874. Ft. Lin.	
Kitty		1,650		
Blygezigt		1,600		
Bel Air		1,250		
Sophia		1,100		
Lilliendaal		1,100		
Patterson		950		
Turkeyen		1,500		
Cumming's Lodge		1,450		
Industry		1,400		
Ogle		1,050		
Goedverwagting		-----		
Sparendaam		150		
Plaisance		450		
Better Hope		100		
Vryheid's Lust		50		
Brothers			3,900	
Montrose			4,600	
Felicity			5,000	
Le Ressouvenir			3,900	
Success			1,300	
Chateau Margot	250			
La Bonne Intention			450	
Beterverwagting			950	
Triumph			600	
Mon Repos			200	
D'Endraght	100			
Good Hope	600			
Two Friends & Nog Eens	1,150			
Lusignan	1,600			
Annandale	1,700			
La Reconnaissance	2,000			
Buxton	1,750			
Friendship	1,150			
Vigilance	1,100			
Bladen Hall	1,000			
Strathspey	750			
Coldingen	800			
Nonpareil	1,250			
Enterprise	1,550			
Elizabeth Hall	1,700			

*Centre of Estate. 1792 Survey by H. V. Cooten, 1874 Survey by A. J. Alcorn.

EAST COAST (Continued)

Alterations in Coast Line Between 1792 and 1874

Estate	Erosion	Accretion
	between 1792 and 1874. Ft. Lin.*	between 1792 and 1874. Ft. Lin.
Bachelor's Adventure	2,400	
Paradise	2,150	
Foulis	1,500	
Hope	1,300	
Enmore	1,500	
Haslington	1,750	
Golden Grove	1,800	
Nabaclis	1,500	
John	1,500	
Cove	1,750	
Craig Miln	2,300	
Victoria	2,400	
Belfield	2,200	
Nooten Zuil	1,500	
Lowlands	1,700	
Hope	1,600	
Dochfour	1,400	
Ann's Grove & Two Friends	1,300	
Clonbrook	800	
Beehive	650	
Greenfield	800	
Orange Nassau	1,300	
Grove	2,050	
Unity	2,400	

Alterations in Coast Line Between 1874 and 1890

Estate	Erosion	Accretion
	between 1874 and 1890. Ft. Lin.†	between 1874 and 1890. Ft. Lin.
Kitty		200
Blygezigt		200
Bel Air	100	
Sophia	500	
Lilliendaal	300	
Patterson	850	
Turkeyen	450	
Cumming's Lodge	550	
Industry	500	
Ogle	400	
Goedverwagting	1,100	
Sparendaam	850	

*Centre of Estate. 1792 Survey by H. V. Cooten, 1874 Survey by A. J. Alcorn.

†Centre of Estate. 1874 Survey by A. J. Alcorn and 1890 Survey by E. A. Pairaudeau.

EAST COAST (Continued)

Alterations in Coast Line Between 1874 and 1890

Estate	Erosion		Accretion	
	between 1874 and 1890. Ft. Lin.*		between 1874 and 1890. Ft. Lin.	
Plaisance	650			
Better Hope	650			
Vryheid's Lust			400	
Brothers	4,000			
Montrose	5,250			
Felicity	5,400			
Le Ressouvenir	5,000			
Success	3,000			
Chateau Margot	2,350			
La Bonne Intention	3,000			
Beterverwagting	4,000			
Triumph	4,000			
Mon Repos	3,650			
D'Endraght	3,400			
Good Hope	2,600			
Two Friends and Nog Eens	2,200			
Annandale	1,650			
Lusignan	1,850			
Le Reconnaissance	1,500			
Buxton	1,800			
Friendship	1,350			
Vigilance	1,150			
Bladen Hall	1,250			
Strathspey	1,300			
Coldingen	1,100			
Nonpareil	1,000			
Enterprise	800			
Elizabeth Hall			150	
Bachelor's Adventure	450			
Paradise	350			
Foulis	700			
Hope	800			
Enmore	550			
Haslington	600			
Golden Grove	850			
Nabaclis	1,000			
John	800			
Cove	600			
Craig Miln	200			
Victoria	150			
Belfield	750			

*Centre of Estate. 1874 Survey by A. J. Alcorn and 1890 Survey by E. A. Pairau-
deau.

EAST COAST (Continued)

Alterations in Coast Line Between 1874 and 1890

Estate	Erosion	Accretion
	between 1874 and 1890. Ft. Lin.*	between 1874 and 1890. Ft. Lin.
Nooten Zuil	600	
Lowlands	800	
Hope	550	
Dochfour	600	
Ann's Grove and Two Friends	800	
Clonbrook	1,000	
Bee Hive	1,000	
Greenfield	850	
Orange Nassau	400	
Grove		
Unity	50	
Lancaster	250	
Leper Asylum	300	

Alterations in Coast Line Between 1890 and 1916.

Estate	Erosion
	between 1890 and 1916. Ft. Lin.†
Kitty	150
Blygezigt	450
Bel Air	400
Sophia	100
Turkeyen	
Cumings Lodge	
Industry	
Ogle	100
Goedverwagting	50
Sparendaam	
Plaisance	50
Better Hope	750
Vryheid's Lust	1,600
Brothers	1,600
Montrose	1,850
Felicity	1,800
Le Ressouvenir	2,350
Success	2,300
Chateau Margot	2,550
La Bonne Intention	1,600
Beterverwagting	950
Triumph	950
Mon Repos	1,050
D'Endraght	900
Good Hope	800

*Centre of Estates. 1874 Survey by A. J. Alcorn and 1890 Survey by E. A. Pairaudeau.

†Centre of Estates. 1890 Survey by E. A. Pairaudeau.

EAST COAST (Continued)

Alterations in Coast Line Between 1890 and 1916

Estate	Erosion	
	between 1890 and 1916.	Ft. Lin.*
Two Friends and Nog Eens	600	
Lusignan	700	
Annandale	650	
Le Reconnaissance	500	
Buxton	550	
Friendship	800	
Vigilance	600	
Bladen Hall	500	
Strathspey	550	
Coldingen	1,500	
Nonpareil	1,000	
Enterprise	1,300	
Elizabeth Hall	500	
Paradise	200	
Foulis	500	
Hope	400	
Enmore	1,000	
Haslington	550	
Golden Grove	200	
Nabacelis	300	
John	400	
Cove	300	
Craig Miln	500	
Victoria	450	
Belfield	300	
Nooten Zuil	400	
Lowlands		
Hope	200	
Dochfour	500	
Ann's Grove and Two Friends	500	
Clonbrook	600	
Bee Hive	700	
Greenfield	700	
Orange Nassau	500	
Grove	200	
Unity	700	
Lancaster	700	
Leper Asylum	400	

West Coast

The report made by Messrs. Smith and Russell in 1871 shows that at that time very severe erosion was taking place between Plantations Best and Leonora, but from the latter Estate to the Boerisirie Creek no

*Centre of Estates. 1890 Survey by E. A. Pairaudeau.

erosion was noticeable. The report of Mr. Hutchens made in 1888 shows that at that date the conditions were the same as in 1871. Subsequent to 1888, very considerable erosion took place between Leonora and the Boerisirie Creek. A short time previous to 1870 a large amount of accretion took place in front of Hague, the growth of the foreshore and courida necessitating the sluice being moved 1,200 feet seaward of its former position. By 1871 the conditions were reversed, and, owing to severe erosion, it became necessary to protect the sluice by fascine work.

The accompanying tables show the actual gain or loss of land at the boundary and center of each estate as indicated by the seaward edge of the courida. Between 1888 and 1909 there was no change in the line of high water in places where the dams were exposed to wave action in 1888 and had since been kept up by fascine work. Between the Best and Windsor Forest the average annual maximum erosion was 45 feet, at the center of line of Union and the minimum erosion 16 feet of the center of Waller's Delight. Between Windsor Forest and Den Amstel there was practically no erosion, this length of coast being protected by fascine work. Between Den Amstel and Fellowship the average annual erosion varied from 9 to 5 feet per annum. Between Hague and Cornelia Ida a very considerable amount of erosion took place between 1888 and 1909, the maximum average erosion, at the center of Cornelia Ida, being 60 feet and the minimum 23 feet, at the boundary line between Hague and Cornelia Ida. The 1909 survey did not go further than Anna Catherina, so that it was impossible to ascertain the changes which took place between that estate and the Boerisirie Creek.

The comparison between the 1888 survey and the survey made for this report (1916), shows that between the Best and Windsor Forest the average rate of erosion per annum has varied from 10 to 28 feet. Between Windsor Forest and Den Amstel there was no change, the dams being protected by fascine work. Between Den Amstel and Anna Catherina the average annual erosion has varied from 41 feet at the center line of Cornelia Ida to 4 feet at the boundary line between Hague and Fellowship. Between Edinburgh and the Boerisirie Creek the average annual erosion in the last 28 years has varied between a maximum of 35 feet at the center of Leonora and a minimum of 6 feet at the center of Edinburgh.

The 1888 survey did not extend beyond the Boerisirie Creek and no accurate map of the coast between there and Parika has since been made. There does not appear, however, to have been any serious erosion.

WEST COAST

Alterations in Coast Line Between 1888 and 1909.

Estate	Erosion between 1888 and 1909.	Average rate of Erosion per annum.	Remarks
	Ft. Lin.	Ft. Lin.	
Boundary Line Nouvelle			
Flanders and L'Union	750	35	
Center Line Union	950	45	

WEST COAST (Continued)

Alterations in Coast Line Between 1888 and 1909.

Estate	Erosion between 1888 and 1909. Ft. Lin.	Average rate of Erosion per annum. Ft. Lin.	Remarks
Boundary Line Union and Rotterdam	700	33	
Center Line Rotterdam	880	42	
Boundary Line Rotterdam and Haarlem	620	29	
Center Line Haarlem	500	23	
Boundary Line Haarlem and Mary	350	17	
Center Line Mary	350	17	
Boundary Line Mary and Waller's Delight	450	21	
Center Line Waller's Delight	340	16	
Boundary Line Waller's Delight and Ruimzigt	600	28	
Center Line Ruimzigt	300	14	
Boundary Line Ruimzigt and Windsor Forest	No chge.	No chge.	Dams protected by Fascines
Center Line Windsor Forest	" "	" "	" " " "
Side Line Windsor Forest and La Jalousie	" "	" "	" " " "
Center Line La Jalousie	" "	" "	" " " "
Side Line La Jalousie and Blankenburg	" "	" "	" " " "
Center Line Blankenburg	" "	" "	" " " "
Side Line Blankenburg and Amstel	" "	" "	" " " "
Center Line Dem Amstel	50	2	
Side Line Dem Amstel and Fellowship	20	9	
Center Line Fellowship	120	5	
Side Line Fellowship and Hague	No chge.	No chge.	Dams protected by Fascines
Center Line Hague	1,100	52	
Boundary Line Hague and Cornelia Ida	500	23	
Center Line Cornelia Ida	1,280	60	
Boundary Line Cornelia Ida and Anna Catherina	No chge.	No chge.	Dams protected by Fascines

WEST COAST (Continued)

Alterations in Coast Line Between 1888 and 1916

Estate	Erosion between 1888 and 1916. Ft. Lin.	Average rate of Erosion per annum. Ft. Lin.	Remarks
Best Koker	300	10	
Boundary Line Nouvelle Flanders and Best	500	17	
Boundary Line Rotterdam and Union	800	28	
Center Line Haarlem	550	19	
Boundary Line Mary and Haarlem	380	13	
Center Line Mary	600	21	
Boundary Line Waller's Delight and Mary	480	17	
Center Line Waller's Delight	560	20	
Boundary Line Ruimzigt and Waller's Delight	800	28	
Center Line Ruimzigt	520	18	
Boundary Line Ruimzigt and Windsor Forest	No chge.	No chge.	Dams protected by Fascines
Center Line Windsor Forest	" "	" "	" " " "
Boundary Line La Jalousie and Windsor Forest	" "	" "	" " " "
Center Line La Jalousie	" "	" "	" " " "
Boundary Line Blankenburg and La Jalousie	80	2	
Center Line Blankenburg	No chge.	No chge.	Dams protected by Fascines
Boundary Line Blankenburg and Dem Amstel	" "	" "	
Center Line Den Amstel	160	5	
Boundary Line Fellowship and Dem Amstel	320	11	
Center Line Fellowship	400	14	
Boundary Line Hague and Fellowship	120	4	
Center Line Hague	900	32	
Boundary Line Cornelia Ida and Hague	780	27	
Center Line Cornelia Ida	1,150	41	
Boundary Line Anna Catherina and Cornelia Ida	200	7	
Boundary Line Edinburgh and Anna Catherina	No chge.	No chge.	Dams protected by Fascines

WEST COAST (Continued)

Alterations in Coast Line Between 1888 and 1916

Estate	Erosion between 1888 and 1916. Ft. Lin.	Average rate of Erosion per annum. Ft. Lin.	Remarks
Center Line Edinburgh	180	6	
Boundary Line Groenveldt and Edinburgh	280	10	
Center Line Groenveldt	250	8	
Boundary Line Groenveldt and Leonora	300	10	
Center Line Leonora	1,000	35	
Boundary Line Stewartville and Leonora	940	33	
Center Line Stewartville	890	31	
Boundary Line Uitvlugt and Stewartville	750	26	
Center Line Uitvlugt	680	24	
Boundary Line Zeeburg and Uitvlugt	350	12	
Center Line Zeeburg	450	16	
Boundary Line De Willem and Zeeburg	500	17	
Center Line De Willem	300	10	
Boundary Line Met-en-Meer- zorg and De Willem	800	28	
Center Line Met-en-Meerzorg	800	28	
West side of Boerasirie Creek	350	12	

ESSEQUEBO COAST

Changes in Coast Line, 1884 to 1917

	Erosion Ft.	Accretion Ft.
Adventure Koker	680	
Onderneeming Industrial School	1,000	
South Side, Public Stelling, Suddie	315	
North Side, " " "		70
Colony House, Suddie		120
Pln. "Belfield"		150
" "Maria's Lodge"	No chge.	
1 Mile Post	" "	
Pln. "Johanna Cecelia"		80
" "Zorg"		70
North end, Pln. "Zorg"	120	

ESSEQUEBO COAST (Continued)

Changes in Coast Line, 1884 to 1917

	Erosion Ft.	Accretion Ft.
South Side Golden Fleece Pier	290	
North " " " "	240	
South " " " Koker	270	
North " " " "	360	
Pln. "Perseverance" Koker	10	
" " " "	330	
" "Cullen"		1,310
" "Abram Zuil"		150
" "Annandale"		380
" "Zorg-en-Vlyt"		470
" "Hoff-van-Aurich"		500
" "Union"		570
" "Dageraad"		530
" "Mocha"		550
" "Westfield"		290
" "Little Alliance"		210
Capoey Police Station	No chge.	
Pln. "Taymouth Manor"		40
" "Affiance"		10
" "Columbia"	90	
" "Aberdeen"	280	
" "Three Friends"	220	
" "Land of Plenty"		20
" "Mainstay"	No chge.	
" "Reliance"	" "	
" "Bush Lot"		300
" "Anna Regina"	50	
" "Henrietta"		30
" "Richmond"	150	
" "La Belle Alliance"	110	
South Side, Lima Koker	480	
North " " " "	260	
Pln. "Coffee Grove"	630	
" "Fear Not"	10	

Owing to the absence of maps, it is impossible to ascertain the amount of erosion which had taken place on the Corentyne Coast. It was obvious, however, that a considerable amount of erosion had taken place in the past and was still going on. Large sums of money were spent in an attempt to save the Public Road, but in January, 1915, a start was made to build a new road at Lots 70 and 71, and since its completion the old road along the shore has been breached and entirely destroyed for a distance of approximately 2,800 feet.

Forces Causing Movement of Foreshore Materials

Before it was possible to arrive at any conclusion as to the causes of erosion and the best method of protection to adopt, it was necessary to carefully consider what were the forces at work on the Coast of Demerara which were active in producing the movement of coast materials resulting in erosion or accretion; acting upon the generally accepted (but too often neglected) principle that a search for the cause should always precede a search for the remedy.

On the East and West Coasts of Demerara, the chief forces tending to cause disintegration and movement of the foreshore materials, were found to be:—

- (1) Waves.
- (2) Wind-formed currents.
- (3) Tidal currents.
- (4) Currents caused by rivers and drainage outlets.
- (5) Wind action.

The investigation made shows that the forces at work on the Essequibo Coast causing the movement of sand and mud are the same as on the East and West Coasts, except that the currents caused by the indraught and the outflow of the Essequibo River have a more powerful influence on the Essequibo Coast than currents formed by the Demerara River have on the East Coast.

On the West Coast the current caused by the indraught and outflow of the Essequibo River also have a more powerful influence than the currents caused by the Demerara River have on the East Coast.

On the East Coast the waves caused by the prevalent winds strike the shore obliquely from an east-northeasterly direction and cause a movement of material westward, i.e., towards the mouth of the Demerara River.

Owing to the trend of the Essequibo Coast, there is a tendency for the waves on the Southern Section of the district to strike the coast more obliquely than they do on the Northern Section, and as a consequence the tendency is for a larger amount of material to be moved per unit area of foreshore. In the neighborhood of Plantation Walton Hall the prevalent onshore winds strike the coast almost at right angles to the shore line, and as a consequence there is no marked tendency for littoral drift to take place in either direction.

Between Walton Hall and the Pomeroon River, and also between the Pomeroon River and the Waini River, the trend of the coast is such that the littoral drift is towards the Northwest. The littoral drift travelling towards the Northwest has caused the waters of the Pomeroon and the Waini Rivers to be diverted a considerable distance along the shore.

On the open coast the alongshore ebb and flood tidal currents flowing in approximately opposite direction oppose one another as transporting agencies. The conclusion arrived at after carefully considering the matter was that tidal currents on the East Coast had little direct effect in causing littoral drift, their chief effect being to transport material previously suspended or disturbed by wave action. In order to ascertain the com-

parative height on the East Coast and at the Government Stelling, Demerara River, tide gauges were set up at Plantations Montrose and Good Hope, these gauges and the one at the Government Stelling being referred to the Georgetown Datum. It was found that on the coast the height of high water spring-tide is about one foot lower than in the Demerara River and that the time of high water on the coast is generally about one hour before high water in the river.

Along the Guiana Coast there is a prevalent drift of water from the mouth of the Amazon to the mouth of the Orinoco River, but the velocity of this coastal current is very small. The flood current alongshore, where not interfered with by the river outlets, flows in a westerly direction and the ebb current in an easterly direction, but owing to the prevalent coastal current flowing from the Amazon towards the Orinoco, the tendency is for material in suspension to move towards the latter river. About 120 miles seaward from the mouth of the harbour, the S. equatorial current flows in a direction N. 33° W. (true) with a velocity of about 1.8 miles per hour. Closer inshore there is a W. drift of water towards the coast by the S. E. trade winds.

Effect of Wind on Height of Tide

The wind velocities on the East Coast are small compared with the velocities on other coasts subject to erosion. During the very high tides at the beginning of February, 1910, the average wind velocity during day and night never reached ten miles per hour; during the following spring-tides the average wind velocity on three occasions reached or exceeded ten miles per hour, but the tide never rose within two feet of the maximum height of the previous spring-tides.

Current Caused by River and Drainage Outlets

On the East Coast of Demarara a considerable amount of water is discharged onto the coast by the Mahaica Creek and through the drainage sluices, locally termed "Kokers," between Mahaica Creek and Plantation Ogle. Owing to the prevalent direction of littoral drift being westward the waters of the Mahaica Creek and previous to the construction of the permanent protection works, various drainage outlets, discharged in a diagonal southwesterly direction across the foreshore. When the tide was flowing inshore the water from the Mahaica Creek was forced close in, and during the rainy season and rough weather the water from this creek could be plainly seen at high tide, close inshore, six miles westward of the Leper Asylum.

Experiments made to find out the direction and velocity of the current resulting from the combined action of tide, wind and drainage outlets show conclusively that on the foreshore between the drainage outlets the prevalent direction of the current is in a westerly direction and that its velocity, under ordinary conditions, is not sufficient to erode material but enough to transport westward material in suspension. Float experiments made

during April, 1916, in front of Plantation Two Friends and Lusignan (between Kokers) showed that from four hours before high water to three hours after high water the surface velocity of the alongshore westerly current never exceeded one foot per second. Four hours before high water the current was from 0.07 to 0.09 foot per second and although irregular, gradually increased in velocity until it was at its maximum about two hours before high water and then gradually decreased in velocity. The current velocities found are insufficient to erode the clay foreshore.

In order to find out the direction of the current on the foreshore during both the flood and ebb of the tide, current indicators were placed on the foreshore in front of Plantation Good Hope, about 100 feet and 200 feet seaward of the dam. The result showed conclusively that the average general direction of the current both before and after high water was approximately parallel to the shore in a westerly direction.

Causes of Erosion

On the Coast of British Guiana erosion was generally noticeable on the leeward side of obstructions to littoral drift, such as dams projecting beyond the general line of sea dams.

It was also found that where shoaling of the sea-bed had taken place on any part of the coast, the tendency was for accretion to take place opposite the shoaling and for erosion to take place on the leeward side, due to interference with the alongshore supply of drift, and that as soon as a pronounced bay was formed the tendency was towards accretion.

It was found, however, that there was a limitation to the amount of localised erosion due to projecting obstructions and changes in the sea-bed. If from any cause, such as interference with littoral drift, erosion took place along a section of the coast, then if this continued a bay was formed.

The line of dam has apparently always been very irregular, and severe erosion has generally taken place at the projecting parts of the dam; when, however, the projecting dams have been abandoned and an artificial bay formed by retiring the dam, accretion as a rule has taken place in front of the new dam.

Erosion Caused by Drainage Outlets

It was found that as a general rule erosion had taken place on the leeward side (on the East Coast, the west side) of the river outlets or drainage channels. Where the amount of alongshore travel of material was large and the amount of water flowing out on the shore small, the damage done to the shore was unimportant; but where the amount of water was comparatively great and the alongshore drift small, very serious erosion had taken place.

When material travelling along the coast encountered the mouth of a river, it was trapped and carried into the estuary or out to sea. The flood tide flowing into the estuary with greater velocity than on the open coast carried in mud and sand to form shoals, while the ebb current, on the contrary, transported material out to sea.



Sand spit formed by unprotected drainage outlet



Marsh in course of formation behind sand bar

Where the amount of material travelling alongshore towards the river mouth was greater than the flood tide moved in or the ebb tide transported seaward, then a spit or submerged bar was formed on the sea side of the outlet, causing the river water to be diverted alongshore. The mouths of the Mahaica, Mahaicony and Abary Creeks all face westward, their outlets in the past being diverted by littoral drift. In 1792 there was a large spit on the East Coast, known as the Lusignan Spit, which was formed by littoral drift diverted by the Korebane Creek. After the diversion of the waters of this creek the spit was gradually washed away.

The view had previously been advanced that drainage outlets did little or no harm as the water was not discharged at high tide when wave action was moving material alongshore. Although the discharge of drainage water across the foreshore at low tide did not act in quite the same way as a river, nevertheless it caused erosion on the leeward side of its outlet. The general practice, however, is to open the sluice door as soon as the level of the water is lower on the sea than on the land side. The tendency on the East Coast is for the channel to form facing towards the west, and the result is that there is deeper water than would otherwise be the case alongshore near the base of the dam; this means greater wave power during storms and consequently greater liability to damage. Where there is a drainage channel across the foreshore, material travelling alongshore tends to accumulate in the channel and block it up. When the sluice is opened the tendency is for the water to move this accumulated material seaward and reform the channel necessary to discharge the water.

There can be little doubt that the erosion of the Coast of British Guiana was due to a considerable extent to the drainage waters being discharged onto the coast without any proper provision being made to prevent injury. The history of the coast seems to show that as the area of land under cultivation and the number of drainage outlets were increased, erosion also increased. The erosion which has taken place east of the Mahaica Creek, where there are few drainage outlets, is much less than the erosion in the East Coast where there were no less than 16 outlets between Georgetown and the Mahaica Canal.

The fact that erosion on the East Coast is partly caused by the untrained drainage outlets and the necessity of taking steps to train the outlets has been repeatedly brought to the attention of the Government. In his report, dated 1890, Mr. W. C. E. Griffith says: "As the estates have extended inland, so much greater the volume of water has been sluiced down through the foreshore through deeper channels, and increasing the scouring action along the whole coast line—thus it appears things went on, the scouring power increasing, till the natural balance and the formation of the foreshore was so far disturbed that a counter-irritation in the shape of an active wash set in, and seeing the very nature and delicate construction of the seashore itself, it is hardly remarkable." In their report to the Government on the foreshore at Plantation Grove, dated 1900, Messrs. Case

and Gray state that "the only serious obstacle to permanent accretion of the foreshore is the untrained flow over it of the Mahaica Canal. The water in finding a course over the foreshore not only keeps the latter at a lower level in the vicinity of the canal, but also affects the shore level for a considerable distance, causing any passing material to be drawn down into the channel and carried out to sea." In a report, dated 1901, the Colonial Civil Engineer, Mr. A. G. Bell, states that "owing to the outlet channel of Mon Repos, discharging along the east side of Triumph, heavy erosion took place, a breach being formed in March, 1893."

Between Plantations Zorg and Perseverance on the Essequibo Coast, a good deal of erosion has taken place since 1884. The maximum erosion being about 360 feet on the north side of Golden Fleece Koker. While the erosion on this section can be partly attributed to the fact that in 1884 it formed a projecting part of the coast, the erosion was mainly due to the fact that the supply of littoral drift was, to a large extent, cut off by the outlet of the Oene Creek. The spit formed diagonally across the foreshore on the windward side of the Creek prevented material being moved onto the stretch of coast between Zorg and Perseverance.

Erosion Caused by Drainage Channels from Swamps

The investigation made seemed to clearly show that on the Corentyne Coast the drainage water from the swamp on the south side of 66 Creek had caused a considerable amount of erosion.

The swamp referred to has an area of about 407 acres. On the west side it is bounded by the Public Road, on the north side by 66 Creek, and on the sea side by a sand ridge overgrown with bush. This swamp not only acts as a catch basin for rain water from the surrounding lands, but at high tide is filled up by water flowing in from a gulley connecting the swamp with 66 Creek; water also overflows from the Creek into the swamp, and tidal water enters through the drainage channel alongshore. At exceptionally high tides, sea water also finds its way over the top of the sand ridge on the sea side. When the tide falls, the bulk of water in the swamp drains out through the alongshore channel and discharges diagonally across the foreshore.

On the part of the Corentyne Coast where the erosion, due to the drainage channel, had cut back a certain length of coast, it was found the tendency was for the projecting part on the leeward side to be gradually cut back by wave and current action until it was in line with the eroded part of the coast.

Destruction of Vegetation

The investigation made showed that on the British Guiana Coast vegetation had been useful in holding and building up areas of foreshore subject to overflow during high tides. Courida (*Aricennia nitida*), Black Mangrove (*Rhizophora Mangle*) and White Mangrove (*Laguncularia racemosa*) being especially useful in muddy places above the breaking point of the waves in building up and consolidating the mud. The roots of these

trees slow down the currents and cause material to be deposited which would otherwise be moved away. The decay of the vegetation itself and the remains of various animals which live among the roots add to the rising surface. Although courida and mangrove trees have proved to be useless to prevent steady erosion by wave action, their ability in building up areas above the line of breaking waves, subject to overflow during high tides, cannot be questioned. In many places where the dams have been retired, considerable areas behind the old dams, not subject to violent wave action, have been built up to nearly high tide level. Between Buxton and Clonbrook the dam is well inland and the foreshore in front has been built up so that the general level on the sea side of the dam is several feet higher than the level on the land side. This accretion must be largely attributed to the action of vegetation. Although, as previously stated, vegetation will not prevent steady erosion taking place by breaking waves, nevertheless areas built up by vegetation are not eroded as quickly as they would have been without the vegetation for two reasons: firstly, the waves have a greater height of foreshore to erode and consequently more material to move; secondly, ground consolidated by a masswork of roots is not so easily attacked as loose mud. There appears to be little doubt that in the past the courida and mangrove on the British Guiana coast have been wantonly destroyed by man and the rate of erosion of the coast thereby increased.

In addition to the cutting of trees for various purposes, the young trees are often destroyed by goats. During the recent inspection of the coast, goats were on several occasions seen eating young trees and shoots. In a number of places the sea-dam itself was found to have been injured by the trampling of goats, pigs and cattle. While the law prohibited the cutting of trees seaward of the dams, and animals straying thereon and on the foreshore, the method of enforcing the laws, especially as regards the straying of animals, appeared to be very inadequate.

Erosion Caused by Dead Trees on the Foreshore

While, as previously pointed out, living trees above the line of breaking waves were found to be of considerable utility in causing accretion, dead trees on the foreshore and seaward of the breaker line were on the contrary found to be very active causes of erosion. Where steady erosion was taking place, owing to wave action, the seamost trees were in time uprooted. Any isolated obstruction which the waves can hit causes scour. This can be seen on almost any shore where a pool of water is found surrounding single piles, stones, etc. On the East Coast there were recently thousands of dead tree stumps on the foreshore, each one of which had caused the shore to be scoured out around it. As soon as the tree stumps were finally uprooted they were sometimes swept on by the waves and used as battering rams to erode the clay foreshore. In some cases the stumps have been continually thrown by the waves against the sea dam until they cut deep channels through the foreshore and into the earth dam itself. On the author's advice many of these were removed before the permanent works were commenced, and the improvement to the shore has been very marked.

Erosion Caused by Removal of Shell

Under natural conditions the tendency in British Guiana is for shell banks to be formed at above high water line, which banks form a natural protection to the low-lying land. Prior to 1916 a considerable amount of shell was removed from the foreshore for road construction and other purposes. As the amount of shell available for building up natural protecting barriers was small, the removal of shell in the past has undoubtedly been detrimental.

Erosion Caused by Sub-Aerial Agencies

When a sandy shore has been formed, as is the case in many places along the coast, sand thrown up by wind action and very high tides has subsequently destroyed by sub-aerial agencies. During dry weather the prevalent onshore winds transport sand inland above high water line; if encouraged by vegetation, the height of the sand ridge will naturally increase and form a defence in front of the sea dams, but where the amount of vegetation is insufficient to retain the sand and the supply brought in by wave action is cut off or materially reduced, then wind action destroyed the sand ridge which it had previously built up. On the Essequibo Coast the sand ridges were noticeably broader, higher and better consolidated whenever they were more or less covered with a species of yellow flowering hibiscus, and it seemed reasonable to assume that if the growth of this shrub was encouraged, the condition of the sand ridges would be improved in many places.

It was also found, as Mr. Leechman in a report to the Sea Defence Commission had previously pointed out, that: "Rain, which is usually heavy in this Colony, tends to flatten the original outline of the sand ridge, and so to render them vulnerable to the action of high tides. The wind-scour is of course at once arrested, but the rain washes the finer particles of sand and the mud down the gentle landward slope, and occasionally cuts deep gulleys in the steep seaward face of the reef. These afford a passage to the incoming tide, and may materially assist in the disintegration of the sand ridge."

Mr. Leechman also pointed out that "the strong and steady trade wind, during dry weather, transports large quantities of sand towards the land, and tends to reduce the height of the sand ridge and so render it vulnerable to the action of very high spring tides, which over-run the ridge, conveying large quantities of sand landwards but also carrying a great deal seawards in the back wash. This is thrown up later further to the west. When overgrown by vegetation especially *sesuvium* the travel of sand by wind agency is much reduced; but it usually happens that only isolated plants are to be found on the reef for a considerable time after its formation, and the bigger these are, the greater is the wind-scour between them."

Erosion Caused by Changes in the Sea Bed

In the Minutes of Proceedings of the Institution of Civil Engineers, 1910-1911, Baron Siccama advances the view that the intermittent erosion

of the Guiana Coast "could be due only to changes in the bed of the sea front. Where this shallowed, the coast to leeward was protected, and where it deepened, the sea waves travelled on coastward in greater volume and velocity with a more disastrous result to that part of the coast on which they impinged."

Unfortunately the sea bed in front of the East Coast has not been recharted since 1886, but a comparison of the charts of 1833 and 1886 gives some interesting information about the erosion of the coast and the changes in the sea bed. Between Plantations Kitty and Industry, considerable erosion of the coast took place between 1833 and 1886, and while the one-fathom line retreated seaward, in some places as much as two miles, showing that while the sea bed was deepening somewhat inshore, further out it was at the same time shallowing.

In front of Plantation Plaisance considerable erosion took place between the above dates but both the one and two-fathom lines retreated seaward, showing that while the coast line was being eroded the sea bed was gradually shallowing. Between Vryheid's Lust and Triumph the coast line grew out between 1833 and 1886, as also did the one and two-fathom lines. Between Mon Repos and Two Friends during the same period the coast was eroded, but both the one and two-fathom lines retreated seawards, erosion of the coast being apparently accompanied by the building up of the sea bed.

While it is obvious that changes in the sea bed opposite any particular stretch of coast must tend to cause erosion or accretion there are many other factors to be considered, and the broad statement of Baron Siccama is not, in the author's opinion, justified by the facts available; but it must be admitted that the absence of frequent re-surveys of the sea bed gives us little information upon which to base definite conclusions.

Erosion Caused by Vertical Sheet Piling

In his reports to the Government, the author stated that severe erosion at Good Hope, Nog Eens and Two Friends on the East Coast and the heavy expenditure incurred in repairing breaches was very largely due to vertical sheet piling. Wherever subjected to the action of breaking waves at high tide, the waves strike the face of the vertical sheeting and project large volumes of water into the air, which falling at the back of the sheeting have scoured away the earth dam, and falling at the toe of the sheeting, have scoured out the mud shore. In 1916 this action could be seen taking place at Nog Eens, and in many other places, where the shore was scoured out below the bottom of the sheet piling. An inspection of this section of the shore at low tide showed the same condition existing along the whole distance between Lusignan Sluice and the bend of the road into Lusignan estate. Where erosion of a foreshore is taking place, due to wave and current action, vertical sheet piling cannot in any way prevent its continuance; all it can do is to postpone the erosion of the land behind and possibly cause some accretion behind the sheet piling if open at one or both ends, while the sea is gradually scouring out the shore in front of the work. Wherever vertical sheet piling is constructed at or seaward of high water

line spring tides on a foreshore which is being eroded by the alongshore or seaward movement of mud or sand, not compensated for by material moved in from the windward side, then after the vertical sheeting is completed, erosion due to the above mentioned causes will still go on and in addition scour will be caused by the waves striking the structure itself. The shore at the toe of the sheeting will gradually get deeper and deeper until the structure is undermined and collapses, as it has done at Nog Eens. Vertical sheet piling on any shore which is being eroded by wave and current action is doomed to destruction unless built above high water line of spring tides or protected, as at Clonbrook, on the East Coast, by a naturally formed mud bank; but in such a case the destructive action will begin should the mud bank be moved away, which the history of the coast shows is most probable unless groynes are constructed to keep it in place.

In order to get some measure of the scour taking place at Two Friends, where the waves were striking the vertical sheeting and eroding the mud at the toe and back of the structure, compared with erosion taking place away from the influence of the sheeting, samples of sea water were obtained at the sheeting and some distance away from it (and outside its influence). It was found that the water at the sheet piling contained 6.19 parts of suspended solids per 1,000 of water, while the sample taken away from the sheet piling contained only 0.73 parts of suspended solids per 1,000 of water. Thus at the sheet piling there was over eight times as much material in suspension as there was outside its influence.

Erosion caused by vertical sheet piling has certainly been going on the West Coast for 28 years, as in 1889 Mr. Griffith in his report on the coast stated, that "in front of Haarlem there could hardly be a better preventative for the making up of the foreshore than almost vertical piling which increased the agitation and wash on the foreshore."

It may be urged that the result of putting in vertical sheet piling in front of Zeeburg and De Willem on the West Coast is inconsistent with the author's emphatic condemnation of such work for coast protection. There is no doubt that if vertical sheet piling is constructed on the foreshore some distance from a sea dam subject to erosion and the sheeting is built up to high water level and is left open at one or both ends, then accretion will take place behind the sheet piling and erosion will probably take place on the windward shore. While land is being built up behind the sheet piling in the area sheltered from violent wave action, erosion will take place in front of the sheet piling and the structure itself which opposes the sea will only be maintained at considerable expense. Accretion behind such structures can only be considered of a temporary nature as the scouring away in front of the structures must end in the vertical piling being undermined and destroyed and then the waves, owing to the deep water in front, can rapidly attack and wash away the land behind.

Erosion Caused by Wave Screens

Prior to 1916 large sums of money had been spent in erecting ridges of stone and stone-filled timber constructions, parallel to the sea dams and a short distance seaward of them. Such wave screens at Plantation Grove,

Lowlands, Triumph, Le Ressouvenir, Success, Good Hope, Buxton, etc., have not only been a failure inasmuch as numerous breaches have occurred and very heavy maintenance expenses incurred in repairing these dams immediately behind the wave screens, but they have, in many cases, also caused serious erosion of the shore in front. Experience in other parts of the world, especially the New Jersey Coast of the United States of America, has proved the futility of trying to protect any coast by wave screens where active erosion is taking place. Attempts made to protect coasts by wave screens built on the foreshore, parallel to high water line, are no doubt due to observation of the fact that accretion nearly always takes place between outlying islands and the main land, but it must not be forgotten that in the case of an outlying island it is always found that the sea side is subject to erosion, and if the island is long and narrow, it will, in course of time, be washed away and when this is accomplished the accretion which took place behind it will also be eroded. On the East Coast in places where there are wave screens, and active erosion is taking place, the result of wave action has been to deepen the shore in front until the waves, owing to the increased depth of water, are able to break over the screen with considerable force and damage or breach the earth dam behind.

In reporting to the Government in 1900, Messrs. Case and Gray drew attention to the erosion at Grove caused by the obstructive action of the detached wave screen. Mr. J. N. Moore, Acting Colonial Civil Engineer, in his report for 1891, referring to the Bel Air estate, said that the stone wave breaker, some distance outside the earth dam, had evidently not effected the object for which it was put down as the sea at high tide was going over the dam in every direction and that the removal of the wave screen was, in his opinion, advisable. This was apparently carried out, but subsequently the construction of wave screens was again commenced on this part of the coast, although they had previously proved a failure. The painstaking observations recently made by Mr. Alleyne Leechman, M.A., on this section of the coast, bear out the conclusions now arrived at, viz.: that the accretion caused by the groynes would be more permanent if the wave screens were taken away. Mr. Leechman states that the wave screens at the northeast corner of the enclosures at Blygezigt "demonstrate that the waves are able to pass through such a structure with ease, to transport sand through it and to set up eddies round and beneath it. Once exposed the water eddies round the rough stones and increases the scour. The action was well illustrated this month at the end of the Sophia swill. Heavy rains have caused this pool to overflow, and the rivulet so formed had followed the line of piled rocks which underlaid the sand and were partly exposed. The erosion was obviously much greater than would have occurred had the stones not been there."

Mr. Griffith in a report made in 1889, also drew attention to erosion at various places on the West Coast, caused by stone-filled timber-wave screens which, as he rightly stated, "often form a centre of a channel following the direction and indicating a scour of increased disturbance in the locality."

On the Essequibo Coast considerable sums of money were also spent in putting down ridges of stone parallel to the sea dam and a short distance seaward of them. Such wave screens are now to be seen in front of Planta-

tions Taymouth Manor, Perseverance, Land of Plenty, Mainstay, Reliance, La Belle Alliance and other facades. In recent years large sums of money have been spent in repairing sea dams immediately behind the wave screens. There is also a stone wave screen along the whole of the facade of Land of Plenty which has proved ineffectual, as practically the whole of this dam was destroyed by high tides and storms between November, 1916, and March, 1917.

Erosion Caused by High Groynes

While groynes are without doubt the cheapest and most effective means of utilizing the forces of nature to build up a natural defence, if correctly designed as regards height, slope, direction, etc., badly designed groynes will often do more harm than good and be active causes of erosion of the coast. In front of Plantations Industry and Cumming's Lodge, there were in 1916, groynes, which, owing to their being built too high above the shore level, were aiding the waves in rapidly eroding the courida bush.

In his annual report for 1908-09, the Colonial Civil Engineer, Mr. J. H. W. Park, stated that the groynes at Mon Repos, Triumph, La Bonne Intention and Chateau Margot "led water directly against the land at their end and increased the rate at which it had eroded." Many of the groynes existing at the period covered by the above report stood high above high water of spring tides and not only caused erosion, but being exposed to the full force of the waves, were continually damaged.

In his annual report for 1908-1909 the Colonial Civil Engineer reported that, "while the groynes from Mosquito Hall to Clonbrook did accumulate material, those lying to the west, with one or two exceptions, had little or no effect. Indeed it would be more correct to say that their effect was detrimental, as in the absence of material to accumulate, they led the water directly against the land at their end and increased the rate at which it was eroded. This action was particularly noticeable at Mon Repos, Triumph, La Bonne Intention and Chateau Margot. Many of the groynes also stood high above high water of spring tides and were therefore exposed to the full force of the waves and continually damaged."

Between Adventure and the south side of the Government Stelling at Suddie, on the Essequibo Coast, considerable erosion has taken place in the past 33 years, the inland movement of high water line in front of the Onderneeming Industrial School being as much as 1,000 feet. The erosion on this section of the coast was no doubt due to the solid part of the road leading to the Stelling projecting across the foreshore and thus forming in effect a high groyne.

In April, 1910, a large breach was made in the sea dam at Nog Eens, and in that year practically the whole fringe of courida between the foreshore and the dam in front of Nog Eens, Two Friends, Good Hope and D'Endraght was washed away. The main cause of the breach was, in the opinion of the Colonial Civil Engineer, the stone groyne a few yards to leeward of the point where it took place. This groyne had a bearing of northeast and standing high above the water, guided the waves against the dam at its end with great force, so destroying the fascines.

Erosion Caused by Stone-Filled Timber Groynes

There are a number of places on the East Coast where the stone-filled timber groynes have done more harm than good. When the waves and current strike the irregular stones, eddies are set up, which cause material to be picked up and carried away in the current. This type of groyne is worse than useless on the lower part of the foreshore where the structure is subject to severe blows. As Mr. Alleyne Leechman has pointed out in his memorandum previously referred to, the erosion at the sea end of the groyne, opposite the west side-line trench of Plantation Turkeyen, has been particularly severe. The groynes between Plantations Lilliendaal and Patterson have also caused erosion by setting up eddies.

On the Essequibo Coast erosion had gradually taken place at Plantation Hampton Court, Sparta and other places, where there were sluice outlets. As the erosion went on, the exposed outlets were protected by artificial works, and in course of time projecting headlands were formed. These projections acted as barriers to the littoral drift, and while they caused accretion on the windward sides, they caused serious erosion on the leeward sides. In a considerable number of cases it was found that the shoreline was cut back quite deeply on the southern or leeward sides of the projecting sluices.



Causes of Littoral Drift

The investigations made show very clearly that the prevalent direction of littoral drift on the East and West Coasts is westerly and that the chief causes of the movement of material are the currents formed by the drainage outlets in their vicinity, and by oblique waves along the whole of the coast. Previous to the construction of the permanent protection works the drainage outlet formed a diagonal current across the shore; each outlet, to some extent, interfered with oblique wave action and the result was a very irregular alongshore travel of material.

The conclusion arrived at with regard to current action, agrees with the opinion of Baron Siccama* that the actual littoral current has no appreciable effect in causing erosion except near the fresh water outlets, and that erosion of the foreshore material is due to the action of waves. The littoral current which itself is incapable of actually eroding material, is, however, a powerful transporting agency, and moves alongshore material stirred into suspension by the waves.

At low tide, oblique and onshore winds transport sand from the foreshore inland. The chief effect of wind action is to erode the foreshore and build up sand ridges above ordinary high tide level, which will themselves be obliterated in course of time unless overgrown with vegetation.

Alongshore Movement of Mud Banks

History shows that on the East Coast of Demerara large mud banks have always been in existence and that they have often, slowly, but still steadily, travelled alongshore from east to west. While a mud bank is in front of

*Vide report of Baron Siccama, 1891.

any particular facade, little or no erosion takes place. In front of Plantation Hope a large amount of erosion took place in 1881, causing the upkeep of the dams to be very expensive. In 1891 a large bank of caddy effectively protected this part of the coast. Previous to 1891 the erosion at or near Bel Air was so serious that the plantation was abandoned, but in that year a bank of material was moved in from the eastward and owing to the Kitty Groyne the accretion has remained ever since.

The section of coast between Mahaica Creek and Clonbrook is a good example of the coast-line changes caused by the formation and subsequent westerly movement of mud banks. In the eighties serious erosion was taking place on this section of the coast; then a mud bank came in and protected the greater part of this section. In 1893 the mud banks had moved westward sufficiently for erosion to again commence, and, gradually increasing in severity, it continued for some years. In 1889 another mud bank made its appearance and gradually moved westward, erosion being again reported in 1901. This history of the other facades on the East Coast is the same, periods of severe erosion being followed by periods when mud banks protected the coast. Mr. Griffith, in his report made in 1889, drew attention to the fact that larger mud banks were formed inshore during southeast land winds than during the prevalent onshore winds and that the banks also remained more or less stationary.

In addition to the mud banks on the foreshore there are numerous sand banks which can be seen at extreme low water. Observations made show that these banks gradually travel westward. Owing to the trend of the coast the prevalent winds strike the shore more obliquely at the western end near Kitty than they do at Mahaica. As a consequence the amount of littoral drift per unit area of foreshore is greater at the western than at the eastern end of the East Coast of Demerara, other conditions being the same.

In his report made in 1889, Mr. Griffith drew attention to the erratic formation and alongshore movement of the mud banks and attributed this primarily to the discharge of drainage waters onto the foreshore. The prevalent winds on this coast are from an east-northeast direction and the oblique wind waves formed thereby cause a prevalent drift in a westerly direction. Owing to the eastern end of this district being to some extent sheltered from the prevalent winds by Georgetown, the westerly travel of material due to wave action is not so marked at the eastern end of the district as it is at the western end. When the tide is flowing the flood current sets in towards both the Essequibo and Demerara Rivers, and as a consequence the tendency is for material transported by currents to be moved in both a westerly and easterly direction from somewhere near the center of the district towards the estuaries of the Essequibo and Demerara Rivers.

Supply of Littoral Drift

Before deciding on the construction of the comprehensive system of protection works it was necessary to ascertain if there was a sufficient supply of material available with which the shore could be built up.

A large number of observations made in the river clearly showed that

the mud in the harbor water is brought in by the flood tide and not brought down by the river. The water in the river is invariably clearer during the ebb than the flood tide. At high tide there is often a considerable quantity of material in suspension, especially at spring tides, but during the latter part of the ebb tide, especially in the rainy season, the water flowing out, although colored by vegetable matter, is almost entirely free from material in suspension. This clearly shows that the silting in the harbor and at the bar is formed of material brought in by the sea and not of material brought down by the river from the uplands.

For a report made by the author for the Government on the Georgetown harbor and bar, investigations were made to ascertain if the material forming the bar were brought down from inland by the Demerara and Essequibo Rivers.*

It was found for practical purposes the supply of material brought down by the British Guiana rivers might be neglected. These rivers do not bring down debris from high and bare mountains, but only drain plains and gentle rolling hills overgrown with dense vegetation. While the waters of the Essequibo River contain a large amount of material in suspension near its mouth, the water is clear and only discolored by vegetable matter a short distance inland. It was therefore obvious that the material in suspension in the water along the coast of British Guiana is derived from some outside source of supply. It is highly probable that the material is brought down by the river Amazon and then transported to the British Guiana Coast by the littoral current.

The amount of material moved along the bottom was found to be very variable, the formation and alongshore movement of the mud banks being erratic. There appeared, however, to be no doubt that a very large reservoir of material existed a short distance seaward of low water line. It was assumed that when the drainage water was directed straight out to sea by the proposed permanent works that there would be a considerably greater supply of material, and that material from the banks seaward of low water line could be moved inward under certain conditions of wind and tide, and could be kept on the foreshore by a suitable system of groyning. That the water along the coast contained a large amount of material in suspension was obvious to anyone and there was no doubt that the material in suspension could be collected and the foreshore built up by properly designed groynes.

The author is indebted to Mr. Robert Harper, chemist for Messrs. Booker Bros., McConnell & Co., Ltd., on the East Coast, for having devoted considerable time in ascertaining the amount of material in suspension in the sea water on the East Coast. The following tables give the results of Mr. Harper's investigations:

Insoluble Solids in Suspension in Sea Water

Sample No.	Date and Place where samples taken	Grains per Gallon of Sediment dried at 100 to 110C.
1	April 29th, 1916, 9:10 a. m. Turkeyen.....	79.1
2	April 29th, 1916, 10:40 a. m. Water discharging from Lusignan Koker	4.2

*Georgetown Harbor and Bar Report by G. O. Case.

Insoluble Solids in Suspension in Sea Water

Sample No.	Date and Place where samples taken	Grains per Gallon of Sediment dried at 100 to 110C.
3	April 29th, 1916, 2:30 p. m. Plaisance.....	28.7
4	April 28th, 1916. Behind Sheet Piling, Two Friends (high tide)	433.3
5	April 29th, 1916, 12 noon, Nog Eens.....	51.1
6	April 29th, 1916, 9 a. m. Kitty Groyne.....	112.0
7	May 1st, 1916, 2:40 p. m. Mahaica.....	67.2

Insoluble Solids in Suspension in Sea Water

	No. 1	No. 2	No. 3
Approximate distance from high water mark	1,000 ft.	1,400 ft.	1,600 ft.
Volume of Sediment per 1,000 of water	8.75	7.25	7.50
Weight of Sediment per 1,000 of water	1.55	1.35	1.34
Grains per gallon of Sediment at 100 to 110	108.5	94.5	93.8
Grains per gallon of Sediment mineral matter after burning	102.9	92.4	86.8
Grains per gallon of Sediment lost on burning	5.6	2.1	7.0
Depth of water time sample was drawn	2.5 ft.	3 ft.	3.5 ft.
Wind 10° N. of E. Light breeze.			

The samples were drawn at 8:45 to 9 a. m. on the 14th of May at Enmore (Hope Groyne) not more than 1 ft. from bottom.

Insoluble Solids in Suspension in Sea Water

	No. 1	No. 2
Approximate distance from high water mark.....	1,000 ft.	600 ft.
Volume of Sediment per 1,000 of water.....	1.0	2.0
Weight of Sediment per 1,000 of water.....	.15	.18
Grains per gallon of Sediment dried at 100 to 110C.	10.5	12.6
Grains per gallon of Sediment mineral matter after burning	9.8	11.9
Wind, a N. E. breeze, with a fair swell on.		
Grains per gallon of Sediment lost on burning.....	.7	.7
Depth of water at time sample was drawn.....	6.5 ft.	5.5 ft.

Waters drawn at 4:10 to 4:30 p. m. on the 16th instant at Enmore (Hope Groyne) not more than 1 ft. from bottom.

Insoluble Solids in Suspension in Sea Water

	No. 1	No. 2	No. 3 Near Low Water Mark
Approximate distance from high water mark	1,000 ft.	1,400 ft.	1,600 ft.
Volume of Sediment per 1,000 of water.....	7.5	10.0	8.5
Weight of Sediment per 1,000 of water.....	1.14	1.17	1.28

Insoluble Solids in Suspension in Sea Water

	No. 1	No. 2	No. 3 Near Low Water Mark
Grains per gallon of Sediment dried at 100 to 110C.	79.80	81.90	89.60
Grains per gallon of Sediment mineral matter after burning	74.90	74.20	78.40
Grains per gallon of Sediment lost on burning	4.90	4.70	11.20

The samples were drawn at 10 a. m. on the 28th April at Enmore (Hope Groyne) and not more than 3 ins. from surface of sea.
A very light breeze.

Total Insoluble Solids in Sea Water

The samples were drawn at 5:30 p. m. on the 6th June, 1916, at Enmore (Hope Groyne) not more than one foot from bottom
Very calm sea and little or no wind.

	No. 1	No. 2
Approximate distance from high water mark.....	1,000 ft.	800 ft.
Volume of Sediment per 1,000 of water.....	3.0	1.5
Weight of Sediment per 1,000 of water.....	.42	.31
Grains per gallon of Sediment dried at 100 to 110C.	29.4	21.7
Grains per gallon of Sediment mineral matter after burning	23.8	14.7
Grains per gallon of Sediment lost on burning.....	5.6	7.0

Total Insoluble Solids in Drain Water

Total solids in water from Enmore main drainage trench, drawn after draining engine had been working one hour, 2nd June, 1916.

Volume of Sediment per 1,000 of water.....	5.25
Weight of Sediment per 1,000 of water.....	1.24
Grains per gallon of Sediment dried at 100 to 110C.....	86.8
Grains per gallon of Sediment mineral matter after burning.....	74.2
Grains per gallon of Sediment lost on burning.....	12.6

After the water was well shaken it was allowed to stand 30 minutes. The amount of suspended matter which had not settled in that time was as follows:

Grains per gallon of Sediment dried at 100 to 110C.....	67.9	18.9
Weight of Sediment per 1,000 of water.....	.97	.27
Grains per gallon of Sediment mineral matter after burning	53.9	20.3
Grains per gallon of Sediment lost on burning.....	14.00	

Total Insoluble Solids in Sea Water

The samples were drawn at 5:30 p. m. on the 6th June, 1916, at Enmore (Hope Groyne) not more than one foot from bottom. Very calm sea and little or no wind.

	No. 1	No. 2
Approximate distance from high water mark.....	1,000 ft	800 ft.
Volume of Sediment per 1,000 of water.....	3.0	1.5
Weight of Sediment per 1,000 of water.....	.42	.31
Grains per gallon of Sediment dried at 100 to 110C.	29.4	21.7
Grains per gallon of Sediment mineral matter after burning	23.8	14.7
Grains per gallon Sediment lost on burning.....	5.6	7.0

The investigation made showed that there was more material moved along the bottom on the West Coast than on the East Coast.

The author found that on the Essequibo Coast there was a very large amount of sand travelling along the shore and also considerable material in suspension in the water.

The conclusion arrived at after considering all the available data was that there was ample supply of material in suspension which could be collected by properly designed groynes. The rapid accretion which has taken place in various places where artificial bays have been formed by retiring the sea-dams corroborated the above opinion. There was also every indication that the supply of material moved along the bottom would increase materially when the drainage waters were directed out to sea.

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